

$h_c(1P)$

$$\Gamma^G(J^{PC}) = ?^?(1^{+-})$$

Quantum numbers are quark model prediction, $C = -$ established by $\eta_c \gamma$ decay.

 $h_c(1P)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
3525.38±0.11 OUR AVERAGE				
[3525.41 ± 0.16 MeV OUR 2012 AVERAGE Scale factor = 1.2]				
3525.31 ± 0.11 ± 0.14	832	1 ABLIKIM	12N BES3	$\psi(2S) \rightarrow \pi^0 \gamma$ hadrons
3525.40 ± 0.13 ± 0.18	3679	ABLIKIM	10B BES3	$\psi(2S) \rightarrow \pi^0 \gamma \eta_c$
3525.20 ± 0.18 ± 0.12	1282	2 DOBBS	08A CLEO	$\psi(2S) \rightarrow \pi^0 \eta_c \gamma$
3525.8 ± 0.2 ± 0.2	13	ANDREOTTI	05B E835	$\bar{p}p \rightarrow \eta_c \gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
3525.6 ± 0.5	92 +23 -22	ADAMS	09 CLEO	$\psi(2S) \rightarrow 2(\pi^+ \pi^- \pi^0)$
3524.4 ± 0.6 ± 0.4	168 ± 40	3 ROSNER	05 CLEO	$\psi(2S) \rightarrow \pi^0 \eta_c \gamma$
3527 ± 8	42	ANTONIAZZI	94 E705	300 π^\pm , $p\text{Li} \rightarrow J/\psi \pi^0 X$
3526.28 ± 0.18 ± 0.19	59	4 ARMSTRONG	92D E760	$\bar{p}p \rightarrow J/\psi \pi^0$
3525.4 ± 0.8 ± 0.4	5	BAGLIN	86 SPEC	$\bar{p}p \rightarrow J/\psi X$

¹With floating width.

²Combination of exclusive and inclusive analyses for the reaction $\psi(2S) \rightarrow \pi^0 h_c \rightarrow \pi^0 \eta_c \gamma$. This result is the average of DOBBS 08A and ROSNER 05.

³Superseded by DOBBS 08A.

⁴Mass central value and systematic error recalculated by us according to Eq. (16) in ARMSTRONG 93B, using the value for the $\psi(2S)$ mass from AULCHENKO 03.

NODE=M144

NODE=M144M

NODE=M144M

NEW

 $h_c(1P)$ WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
0.70±0.28±0.22		832	5 ABLIKIM	12N BES3	$\psi(2S) \rightarrow \pi^0 \gamma$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 1.44	90	3679	6 ABLIKIM	10B BES3	$\psi(2S) \rightarrow \pi^0 \gamma \eta_c$
< 1		13	ANDREOTTI	05B E835	$\bar{p}p \rightarrow \eta_c \gamma$
< 1.1	90	59	ARMSTRONG	92D E760	$\bar{p}p \rightarrow J/\psi \pi^0$

⁵With floating mass.

⁶The central value is $\Gamma = 0.73 \pm 0.45 \pm 0.28$ MeV.

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NODE=M144M;LINKAGE=RO

NODE=M144M;LINKAGE=NW

NODE=M144W

NODE=M144W

NODE=M144W;LINKAGE=AL

NODE=M144W;LINKAGE=AB

NODE=M144215;NODE=M144

 $h_c(1P)$ DECAY MODES

Mode	Fraction (Γ_i/Γ)
$\Gamma_1 J/\psi(1S) \pi^0$	
$\Gamma_2 J/\psi(1S) \pi \pi$	not seen
$\Gamma_3 p\bar{p}$	
$\Gamma_4 \eta_c(1S) \gamma$	(51 ± 6) %
$\Gamma_5 \pi^+ \pi^- \pi^0$	< 2.2 × 10 ⁻³
$\Gamma_6 2\pi^+ 2\pi^- \pi^0$	(2.2 ^{+0.8} _{-0.7}) %
$\Gamma_7 3\pi^+ 3\pi^- \pi^0$	< 2.9 %

DESIG=1

DESIG=2;OUR EST;→ UNCHECKED ←

DESIG=3

DESIG=4

DESIG=5

DESIG=6

DESIG=7

NODE=M144220

NODE=M144223

NODE=M144G1

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NODE=M144G1;LINKAGE=AN

 $h_c(1P)$ PARTIAL WIDTHS **$h_c(1P) \Gamma(i)\Gamma(\bar{p}p)/\Gamma(\text{total})$**

$\Gamma(\eta_c(1S)\gamma) \times \Gamma(p\bar{p})/\Gamma_{\text{total}}$	$\Gamma_4 \Gamma_3/\Gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •	
12.0 ± 4.5	13 7 ANDREOTTI 05B E835 $\bar{p}p \rightarrow \eta_c \gamma$

⁷Assuming $\Gamma = 1$ MeV.

$h_c(1P)$ BRANCHING RATIOS

$\Gamma(J/\psi(1S)\pi\pi)/\Gamma(J/\psi(1S)\pi^0)$					Γ_2/Γ_1
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<0.18	90	ARMSTRONG	92D	$\bar{p}p \rightarrow J/\psi\pi^0$	

$\Gamma(\eta_c(1S)\gamma)/\Gamma_{\text{total}}$					Γ_4/Γ
VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT	
51 ± 6 OUR AVERAGE					

54.3 ± 6.7 ± 5.2	3679	ABLIKIM	10B	$BES3 \psi(2S) \rightarrow \pi^0 \gamma \eta_c$	Γ_4/Γ
48 ± 6 ± 7	8 DOBBS	DOBBS	08A	$CLEO \psi(2S) \rightarrow \pi^0 \eta_c \gamma$	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
48 ± 6 ± 7	1282	9 DOBBS	08A	$CLEO \psi(2S) \rightarrow \pi^0 \eta_c \gamma$	
46 ± 12 ± 7	168	10 ROSNER	05	$CLEO \psi(2S) \rightarrow \pi^0 \eta_c \gamma$	

8 Average of DOBBS 08A and ROSNER 05. DOBBS 08A reports $[\Gamma(h_c(1P) \rightarrow \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))] = (4.16 \pm 0.30 \pm 0.37) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.					
9 DOBBS 08A reports $[\Gamma(h_c(1P) \rightarrow \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))] = (4.19 \pm 0.32 \pm 0.45) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.					
10 ROSNER 05 reports $[\Gamma(h_c(1P) \rightarrow \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))] = (4.0 \pm 0.8 \pm 0.7) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.					

$\Gamma(\pi^+ \pi^- \pi^0)/\Gamma_{\text{total}}$					Γ_5/Γ
VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN	COMMENT	
<2.2	11 ADAMS	09	CLEO	$\psi(2S) \rightarrow \pi^0 \gamma \eta_c$	

11 ADAMS 09 reports $[\Gamma(h_c(1P) \rightarrow \pi^+ \pi^- \pi^0)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))] < 0.19 \times 10^{-5}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = 8.6 \times 10^{-4}$.

$\Gamma(2\pi^+ 2\pi^- \pi^0)/\Gamma_{\text{total}}$					Γ_6/Γ
VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT	
2.2 ± 0.8 ± 0.3	92	12 ADAMS	09	CLEO $\psi(2S) \rightarrow \pi^0 \gamma \eta_c$	

12 ADAMS 09 reports $[\Gamma(h_c(1P) \rightarrow 2\pi^+ 2\pi^- \pi^0)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))] = (1.88 \pm 0.48 \pm 0.47) \times 10^{-5}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(3\pi^+ 3\pi^- \pi^0)/\Gamma_{\text{total}}$					Γ_7/Γ
VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT	
<2.9	13 ADAMS	09	CLEO	$\psi(2S) \rightarrow \pi^0 \gamma \eta_c$	

13 ADAMS 09 reports $[\Gamma(h_c(1P) \rightarrow 3\pi^+ 3\pi^- \pi^0)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))] < 2.5 \times 10^{-5}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = 8.6 \times 10^{-4}$.

$\Gamma(h_c(1P) \rightarrow \eta_c(1S)\gamma)/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \pi^0 h_c(1P))/\Gamma_{\text{total}}$					$\Gamma_4/\Gamma \times \Gamma_{15}^{\psi(2S)}/\Gamma^{\psi(2S)}$
VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT	
4.3 ± 0.4 OUR AVERAGE					

4.58 ± 0.40 ± 0.50 3679 14 ABLIKIM 10B BES3 $\psi(2S) \rightarrow \pi^0 \gamma X$
 4.16 ± 0.30 ± 0.37 1430 15 DOBBS 08A CLEO $\psi(2S) \rightarrow \pi^0 \gamma \eta_c$

14 Not independent of other branching fractions in ABLIKIM 10B.
 15 Not independent of other branching fractions in DOBBS 08A.

 $h_c(1P)$ REFERENCES

ABLIKIM	12N	PR D86 092009	M. Ablikim <i>et al.</i>	(BES III Collab.)
ABLIKIM	10B	PR D104 132002	M. Ablikim <i>et al.</i>	(BES III Collab.)
ADAMS	09	PR D80 051106	G.S. Adams <i>et al.</i>	(CLEO Collab.)
DOBBS	08A	PRL 101 182003	S. Dobbs <i>et al.</i>	(CLEO Collab.)
ANDREOTTI	05B	PR D72 032001	M. Andreotti <i>et al.</i>	(FNAL E835 Collab.)
ROSNER	05	PRL 95 102003	J.L. Rosner <i>et al.</i>	(CLEO Collab.)
AULCHENKO	03	PL B573 63	V.M. Aulchenko <i>et al.</i>	(KEDR Collab.)
ANTONIAZZI	94	PR D50 4258	L. Antoniazz <i>et al.</i>	(E705 Collab.)
ARMSTRONG	93B	PR D47 772	T.A. Armstrong <i>et al.</i>	(FNAL E760 Collab.)
ARMSTRONG	92D	PRL 69 2337	T.A. Armstrong <i>et al.</i>	(FNAL, FERR, GENO+)
BAGLIN	86	PL B171 135	C. Baglin <i>et al.</i>	(LAPP, CERN, TORI, STRB+)

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